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THE APPLICATION OF TRITIUM DATING TECHNIQUES TO WATER INFLOWS EXPERIENCED AT THE DONKIN MORIEN PROJECT, NOVA SCOTIA

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THE APPLICATION OF TRITIUM DATING TECHNIQUES TO WATER INFLOWS EXPERIENCED AT THE DONKIN-MORIEN PROJECT, NOVA SCOTIA

by

T.R.C. Aston*

SUMMARY

In the first 500 m of the Donkin-Morien Development Project, some water feeders were encountered which constituted a nuisance rather than a hazard to the drivage operations. A limited programme of tritium analyses were undertaken on selected No. 3 tunnel inflows in an attempt to establish the age, source horizon and recharge mechanism of the ingress water.

A comparison of surface and underground samples reveals that the water is 'modern' in age (pre-1952). However, it is considered from the available data that the results should only be used to supplement the analysis and interpretation of existing hydrological and hydrochemical data presently being collected.

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L'APPLICATION DES MÉTHODES DE DATATION AU TRITIUM AUX ARRIVÉES D'EAU AU PROJET DONKIN-MORIEN EN NOUVELLE-ÉCOSSE

par

T.R.C. Aston*

RÉSUMÉ

Dans les premiers 500 m au projet de mise en valeur Donkin-Morien on a rencontré des sources d'eau qui se sont avérées gênantes plutôt que dangereuses lors des travaux de percement. On a entrepris un programme restreint de dosages du tritium à des arrivées choisies dans la galerie n° 3 afin de déterminer l'âge et l'horizon d'origine de l'eau ainsi que le mécanisme d'alimentation.

La comparaison des échantillons recueillis en surface et sous terre révèle que l'eau est "moderne" (pré-1952). Toutefois d'après les données disponibles on considère que les résultats ne devraient être utilisés que pour compléter l'analyse et l'interprétation des données hydrologiques et hydrochimiques existantes que l'on recueille présentement.

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INTRODUCTION

The Cape Breton Development Corporation Donkin-Morien Project is located at Cape Perce, Cape Breton Island. Phase II of the project involves the construction of two parallel access tunnels (Nos. 2 and 3), 3.7 km in length to intersect the Harbour Coal seam. At present, 1027 m of the No. 3 tunnel has been driven using drill and blast methods. In the first 500 m of tunnel No. 3 some water feeders were encountered which constituted a nuisance rather than a hazard to the tunnelling operations. All the available data regarding these inflows has been collected and is currently undergoing re-assessment by CBCRL, CBDC and Golder personnel.

In January 1983, CBCRL staff initiated a limited programme of tritium analyses on selected No. 3 tunnel inflows in an attempt to establish the age, source horizon and recharge mechanism of the ingress water.

TRITIUM DATING GROUNDWATER

Tritium (^{3}H) is a natural radioactive isotope of hydrogen which is formed by the interaction of cosmic rays with nitrogen. It is a weak beta ray emitter with a half life of 12.26 years and is also a by-product of thermonuclear testing.

The widespread testing 'above ground' of thermonuclear devices between 1952 and 1962 drastically increased the amount of tritium in the atmosphere, swamping natural background levels. The intermittent testing of such devices has also led to the introduction of periodic pulses or peaks of tritium to the atmosphere.

Tritium usually enters the hydrological cycle (Appendix A) via precipitation. Figures 1 and 2 show tritium variations in precipitation over Canada (1) and Great Britain (2) for the period 1953 to 1975. An indication of the periodic nature of atmospheric tritium levels is given by both figures as well as the relationship between peak levels and those years in which major 'above ground' testing occurred. However, it should be remembered that the amount of tritium input to the earth's surface is variable and dependent on climatic conditions as illustrated by the following statement (2):

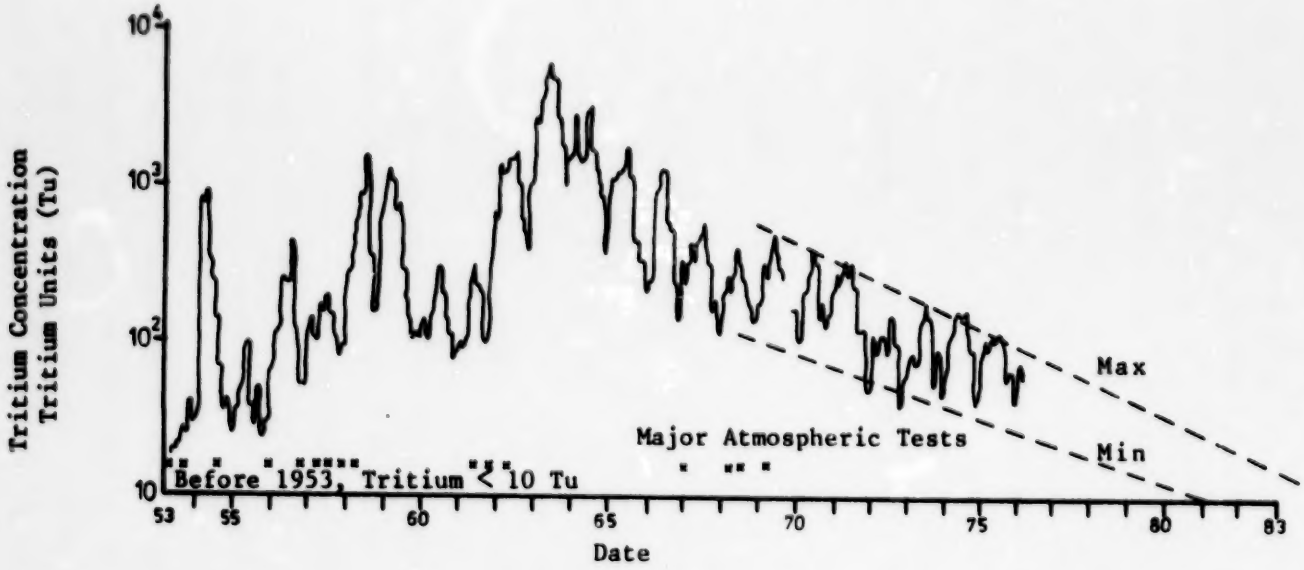

Figure 1 - Tritium concentrations in precipitation (mean monthly values), Ottawa, Canada

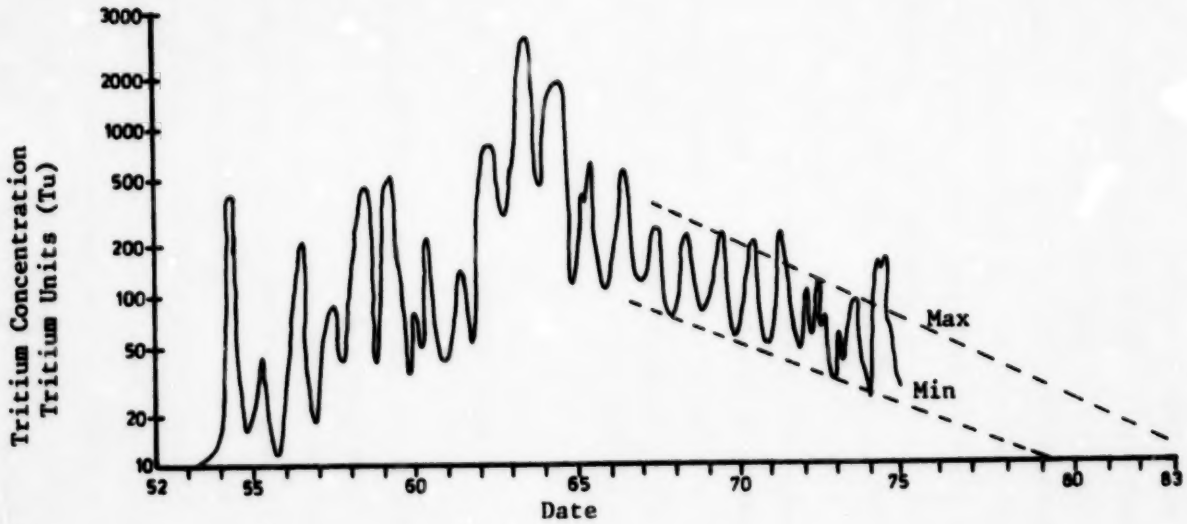

Figure 2 - Tritium concentrations in precipitation over the United Kingdom.

'In oceanic areas vapour exchange between the atmosphere and sea will be far more effective than precipitation in removing tritium concentrations from the atmosphere. Over land areas the removal of atmospheric tritium is principally via precipitation, which is extremely variable and dependent on the various climatic, land distance and orographic influences affecting precipitation. It is therefore apparent that tritium concentrations reaching the earth's surface can be exceedingly variable in both time and space. Consequently, tritium levels in groundwater via both direct and indirect recharge can also be extremely variable'.

If the problems associated with using tritium are recognized, then in simplified terms the apparent age of groundwater can be determined by its classification according to one of three types:

1) No detectable tritium - Older than 100 years
2) Low levels of tritium - Pre-1952
3) High levels of tritium - Post-1952

A more detailed discussion of the assumptions necessary and potential problems encountered when using tritium to date groundwater is given elsewhere (1), (2).

WATER OCCURRENCES IN THE NO. 3 TUNNEL

In tunnel No. 3 water seepage and inflows were encountered during the first 500 m of drivage. They appeared to be associated with a clay seam which loosely followed a conglomerate band near the top of the main sandstone unit. During the first 300 m, the conglomerate and clay layer were often exposed in the tunnel section which resulted in water inflows at these locations. In addition, inflows were also experienced from open fissures created by the drill and blast operations used in this section. Between 300 and 500 m, the nature of the inflows changed with water only being encountered in rock bolt holes which intersected the clay/conglomerate horizon.

All available data concerning water inflows in the No. 3 tunnel has been collected and is currently undergoing re-assessment by CBCRL, CBDC and Golder personnel.

DATA COLLECTION

Water samples were collected from two locations in the No. 3 tunnel and one surface site. The underground samples were collected from water 'feeders' at chainage 300 m and 500 m, while the surface water sample was collected from the sea at the nearby Donkin beach. In each case, the samples were collected in sterile one litre plastic screw top bottles on site, sealed and subsequently shipped to the Analytical Service Section of Ontario Hydro, Toronto for analysis.

Samples were analyzed for tritium and inorganic carbon - 14 counts. The tritium count was measured using liquid scintillation counting over a 100 min. period. The inorganic carbon - 14 count was measured using acid digestion/distillation preconcentration followed by liquid scintillation counting.

The Ontario Hydro results are given in Appendix B.

ANALYSIS AND DISCUSSION OF RESULTS

Test results in Appendix B give the tritium concentration as a value in pico curies (pC) per litre. In references (1), (2) and (3) the atmospheric and groundwater tritium values are always expressed in Tritium Units (TU's). It is therefore necessary to convert pC/litre to Tritium Units:

1 TU = 7.20 dpm (disintegrations per minute)

1 Curie = 2.22×10^{12} dps

= 3.70×10^{10} dpm

1 Pico = 10^{-12}

Therefore 1 pC = 3.7×10^{-2} dpm.

If the tritium count of seawater is 1200 pC then

$1200 \times 3.7 \times 10^{-2} = 44.4$ dpm

and $\frac{44.4}{7.2}$ 6.0 TU.

The analysis of tritium in samples of distilled, deionized and tap water was also undertaken with the field samples. Table 1 shows the minimum, mean and maximum results obtained for the samples in Tritium Units (TU). Unfortunately, when reviewing Table 1, it can be seen that extreme caution must be exercised when attempting to interpret the results. In both Table 1 and Appendix B a large potential error exists for each of the results. It is therefore necessary to assume that for each of the six samples analyzed, the mean value is representative of the inherent tritium concentration.

The samples collected from chainage 300 and 500 (9 and 8 TU) show marginally greater tritium concentrations than the seawater sample (6 TU). The samples of distilled, deionized and tap water show a variation between 8 and 10 TU, indicating that modern values can be expected to lie in this region. The seawater value of 6 TU is slightly lower than that indicated by the comparable modern samples (8-10 TU).

A direct comparison of the modern and underground samples indicates that all are 'modern' in age. Lloyd (2) states that 'a concentration of over 4 TU can provide a signature for the water type inferring simply that modern recharge is a feature'. Since neither very high nor very low tritium concentrations are present, it can be inferred that the chainage 300 and 500 feeders are associated with an aquifer horizon which was recharged during the pre-1952 era.

Alternatively, if the tritium concentrations in the rainfall of Figures 1 and 2 are extrapolated to the year 1983 then the expected mean tritium concentration lies between 5 and 15 TU (assuming no further thermonuclear testing during this period). If it is also accepted that variations in tritium can occur due to the reasons stated in the section 'Tritium Dating Groundwater', then the water experienced in the No. 3 tunnel could be recent in age (less than 5 years). This would indicate that rapid recharge was occurring either vertically downwards from seabed or down dip from the outcrop.

Sample	No.	Minimum	Mean	Maximum
Seawater	51	2.0 (2)	6.2 (6)	10.3 (10)
300 m	52	2.6 (3)	8.7 (9)	14.9 (15)
500 m	53	2.0 (2)	7.7 (8)	13.4 (13)
Distilled Water	54	3.6 (4)	10.3 (10)	16.9 (17)
Deionized Water	55	2.6 (3)	8.2 (8)	13.9 (14)
Tap Water	56	3.1 (3)	9.2 (9)	15.4 (15)

Table 1 - Tritium values for the six samples analyzed.

CARBON - 14 DATING

No meaningful results were obtained from the Carbon - 14 analyses undertaken. In each case, the carbon - 14 count was found to be less than pC 15 and the exact value not specified because of insufficient sensitivity in the test method.

If future work were to be undertaken, it should be determined beforehand whether the analytical method can be refined sufficiently in order to give a definite carbon - 14 value.

CONCLUSION

The results indicate that the two feeders monitored at chainages 300 and 500 m in the Donkin-Morien No. 3 tunnel are discharging water which is at least 'modern' in age (pre-1952). However, because of the scant amount of data available as well as the inherent problems of using tritium as a method for determining the age and source horizon of the groundwater feeders, it is considered that the current results should only be used to supplement the analysis and interpretation of existing hydrological and hydrochemical data sets presently being collected.

ACKNOWLEDGEMENTS

The Cape Breton Coal Research Laboratory gratefully acknowledges the support and assistance of the Cape Breton Development Corporation personnel at the Donkin-Morien Project. In addition, thanks are also due to Golder Associates and Ontario Hydro Research for their assistance with this work.

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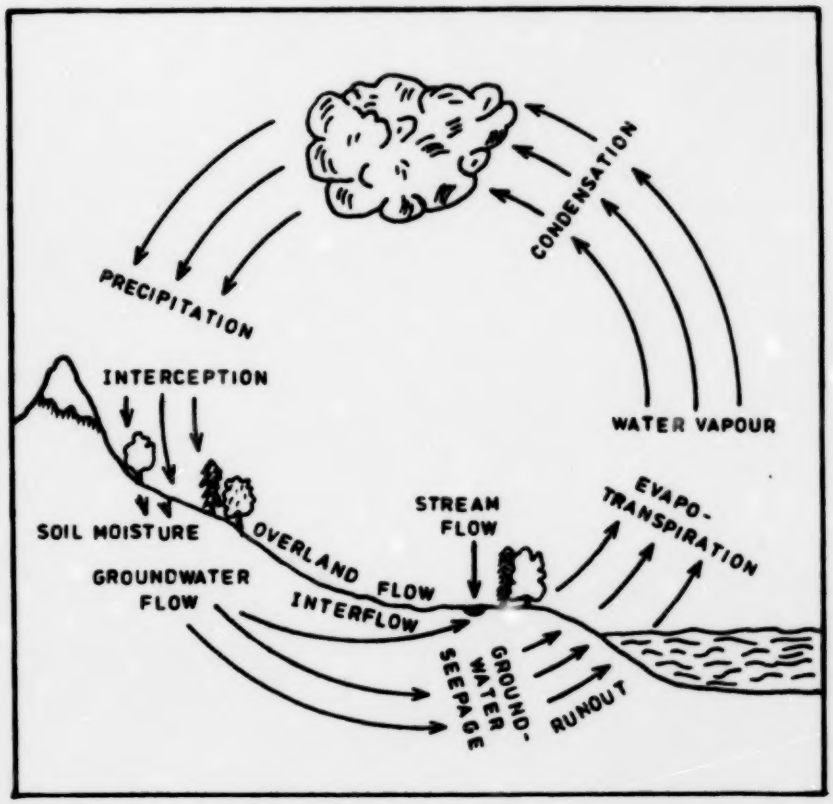
APPENDIX A



The Hydrological Cycle (Ward (4))

APPENDIX B

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Date Received:Feb 8, 1983
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REPORT OF CHEMICAL ANALYSIS

1. Sample Description
3 SAMPLES OF WATER FROM DONKIN MORIEN

2. Analysis Required
TRITIUM (H3) BY LIQUID SCINTILLATION COUNTING FOR 100 MINS.
INORGANIC CARBON-14 (C14) BY ACID DIGESTION/DISTILLATION PRECONCENTRATION FOLLOWED BY LIQUID SCINTILLATION COUNTING.

3. Comments
DETERMINATION LIMIT FOR C14 BASED ON THE 2 SIGMA COUNTING ERROR FOR THE METHOD BLANK. UNCERTAINTY IN H3 DATA DERIVED FROM THE 2 SIGMA COUNTING ERRORS FOR EACH SAMPLE & THE BLANK

RESULTS APPEAR IN APPENDED TABLE(S)

Approved:

M.R. Booth
Supervising Chemist
Analytic Services Section
Chemical Research Department

Submitted:

for K.E. Curtis
Chemist
Analytic Services Section

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TABLE(S) OF RESULTS

Table(1, 1). Sample 1 to 6 versus Analyte 1 to 2

	Name	Analyte 1	Analyte 2
Name		H3 (pCi/L)	C14 (pCi/L)
S 1	SEAWATER	1200+/-800	<15
S 2	300M	1700+/-1200	<15
S 3	500M	1500+/-1100	<15
S 4	DISTILLED WATER	2000+/-1300	<15
S 5	DEIONIZED WATER	1600+/-1100	<15
S 6	TAP WATER	1800+/-1200	<15